INTEGRATED TRANSMITTERS AND LONG-WAVELENGTH VCSELs

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13. ABSTRACT (Maximum 200 words)

The objective of this program is to develop InP-based monolithically integrated transmitters, including internal (current) and external modulation. The basic issues involved in such integration and operation of the individual devices will be explored both theoretically and experimentally. Thus, intrinsic and extrinsic factors that limit internal and external modulation, propagation and scattering of light in guided structires and through mirrors, and circuits, materials and lithography issues to develop high-frequency (>30 GHz) transmitters will be explored. Integrated chips with driver circuits and guided wave elements will be developed and tested.

At the same time we are also developing novel top- and edge-emitting microcavity laser structures in which zero or very low threshold currents are expected due to phonon confinement. Preliminary results, both theoretical and experimental, are very encouraging, and we envisage that these low threshold, high frequency devices will be extremely useful for chip-to-chip and array-based optical interconnects.

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Objective

To design, fabricate and characterize microcavity lasers and LEDs and 1.55μm monolithically integrated transmitters.

Progress

1. 1.55μm oxide-confined VCSELs

We have successfully demonstrated low threshold (5mA) oxide confined InP-based VCSELs with quasi-CW operation at room temperature and high T_o. This unique device, called the patterned VCSEL, has a GaAs-based *defect-free* DBR, made by patterned regrowth. The output has stable polarization and a small beam divergence of only 15°. Our technique for making large-scale VCSEL arrays.

Work is in progress to lower the threshold current to ~1mA, to achieve CW operation at room temperature, and to fabricate and characterize arrays.

2. Electrically Injected Single Defect Photonic Bandgap Surface-Emitting Laser at Room Temperature

A single defect in a two- or three-dimensional photonic bandgap (PBG) crystal forms a tirue microcavity and it is possible to achieve a single-mode LED, or a zero-threshold laser, with such microcavity, *without the use of mirrors*. We have recently demonstrated, for the first time, an electrically injected (previous work was only with optically excited PBG microcavity) defect-mode PBG microcavity surface emitting laser at room temperature. 931 nm lasing was observed with I_{th}=300μA. Near- and far-infrared model characteristics confirm lasing from the defect-related microcavity in the photonic bandgap crystal. *It may be noted that the laser has no mirrors.*

Work is in progress to demonstrate a zero threshold PBG-Defect laser at 1.55μm and arrays of these devices.

3. High-Power InP-Based 1.55μm Microcavity Light Emitting Diodes

For array applications, it would be technologically simpler to have surface-emitting light sources *without* DBR mirrors. To this end, we have investigated, designed, fabricated and characterized InP-based, oxide-confined microcavity LEDs for the first time. The smallest devices have a cavity radius of 0.5μm. The output power is ~30μW and due to microcavity effects, the output is very directional (angular width 20 degrees, compared to 50 degrees of conventional LEDs). We have measured the small signal bandwidths of these devices to be ~ 0.8 GHz. The devices are therefore comparable to VCSELs, but has much simpler fabrication technology, particularly for arrays.

4. Integrated 1.55μm VCSEL-Modulator

We are currently fabricating an integrated 1.55μm VCSEL-modulator, in which the modulating region forms an integral part of the top DBR. We have analyzed the performance characteristics of the device exhibits an intrinsic modulation bandwidth of ~50 GHz with very low chirp.

Publications

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1. "Growth and Characterization of Defect-Free GaAs/AlAs Distributed Bragg Reflector Mirrors on Patterned InP-Based Heterostructures", H. Gebretsadik, K. Kamath, K.K. Linder, P. Bhattacharya, C. Caneau and R. Bhat, *J. Vac. Science and Technology,* **B-16**, (1998).
2. "InP-Based 1.5μm Vertical Cavity Surface Emitting Laser with Epitaxially Grown Defect-Free GaAs-Based Distributed Bragg Reflectors", H. Gebretsadik, P. Bhattacharya, K. Kamath, O. Qasaimeh, D. Klotzkin, C. Caneau and R. Bhat, *Electronics Letters,* **34**, 1316 (1998).
3. "Design and Realization of a 1.55μm Patterned VCSEL with Lattice-Mismatched Mirror Layers.", H. Gebretsadik, O. Qasaimeh, H. Jiang, P. Bhattacharya, C. Caneau, and R. Bhat, *IEEE Journal of Lightwave Technology*, (1999).
4. "Electrically injected single-defect photonic bandgap surface-emitting laser at room temperature", W.D. Zhou, J. Sabarinathan, B. Kochman, E. Berg, O. Qasaimeh, S. Pang and P. Bhattacharya, *Electronics Lett.*, **36**, no. 18, (2000).

Conference Presentations

1. "1.55μm Patterned VCSELs with Mismatched Mirrors", (INVITED), P. Bhattacharya, *IEEE/LEOS Summer Topical Meetings* San Diego, CA, July, 1999.

2. "Processing and Characterization of a GaAs/Al_xO_y Quasi-Three Dimensional Photonic Bandgap Material", W.D> Zhou, P. Bhattacharya, J. Sabarinathan, D.H. Zhu, A.S. Helmy, and J.H. Marsh, *IEEE Lasers and Electro-Optics Society Annual Meeting,* San Francisco, CA, November, 1999.
3. "Patterned 1.54μm Vertically Cavity Laser with Mismatched Defect-Free Mirrors", O. Qasaimeh, H. Gebretsadik, P. Bhattacharya, C. Caneau, and R. Bhat, *IEEE International Electron Devices Meeting,* Washington, D.C., December, 1999.

4. "InP-Based Oxide-Confined 1.55-1.6μm Microcavity Light-Emitting Diodes", W. Zhou, O. Qasaimeh and P. Bhattacharya, *SPIE Photonics West,* San Jose, CA, January, 2000.